<u>EXHIBIT III</u>

DRAFT March 05 2001, 1548PM

COMPONENT SPECIFICATION
CS 518574

FOR
Ku-BAND PULSED TRAVELING-WAVE TUBE AMPLIFIER (TWTA)
ON THE OCEAN VECTOR WINDS MISSION SCATTEROMETER

CHANGE INCORPORATION LOG

	RELEASE			PAGES		ENG. APPROVAL	
REV	INITIAL	SECTION	AUTHORITY	AFFECTED	DATE	INITIAL	SECTION
A	initial	336	unreleased	All			336

1. SCOPE

This specification establishes the requirements for performance, design, fabrication, test, quality assurance provision, shipping, and transportation of pulsed radar Traveling-Wave Tube Amplifier (TWTA). The TWTA is composed of a Traveling-Wave Tube (TWT), and a High Voltage Power Supply (HVPS) for use in the Ocean Vector Winds Mission (OVWM) Scatterometer Radio Frequency Subsystem (Scatterometer). The OVWM Scatterometer carries redundant TWTAs.

1.1. APPLICABLE DOCUMENTS

The documents referenced in Exhibit I, “Applicable Documents List”, form a part of this specification to the extent specified herein. In case of conflict between the requirements of this document and the requirements of any documents referenced herein, the conflict shall be referred to the JPL’s Contract Technical Manager for resolution.

JPL intends that the contractor maximize the use of his existing documentation wherever possible provided that the contractor documents are essentially equivalent to and meet the intent of JPL’s controlling and lower tier documents. JPL expects that the contractor plans, when approved by JPL, will replace the equivalent JPL controlling or lower tier document(s).

1.2. Abbreviations

In addition to common abbreviations, the following abbreviations are used throughout this document.

BOL	Beginning of life
CW	Continuous Wave
DC	Direct Current
EM	Engineering Model
EMC	Electromagnetic Countability
EMI	Electromagnetic Interference
EOL	End of life
EQM	Engineering Qualification Model
FA	Flight Acceptance
C&DH	Command and Data Handling
DSS	Digital Subsystem
FM	Flight Model

HVPS	High Voltage Power Supply
ICD	Interface Control Drawing
J	Joules
JPL	Jet Propulsion Laboratory
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
OVWM	Ocean Vector Winds Mission
Qual	Qualification
p-p	Peak to peak
PFM	Protoflight Model
PRI	Pulse Repetition Interval
pps	Pulses per second
PRF	Pulse Repetition Frequency
RF	Radio Frequency
RTN	Return
TWT	Traveling Wave Tube
TWTA	Traveling Wave Tube Amplifier
VSWR	Voltage Standing Wave Ratio
LVDS	Low Voltage Differential Signaling
SRS	Shock Response Spectra
STE	Special Test Equipment
NPSL	NASA Parts Selection List

2. Requirements

2.1. Functional Requirements

2.1.1. TRAVELING-WAVE-TUBE AMPLIFIER (TWTA)

The OVWM pulsed radar Ku-band TWTA consists of a Traveling Wave Tube (TWT) and a High Voltage Power Supply (HVPS). The TWT will amplify low-level RF pulses from the OVWM Scatterometer to a high power. The amplifier will be "gated" on and off by means of a pulse control signal. While gated on, the TWTA will be operated only in a saturated output condition.

A functional block diagram is shown in Figure 1.

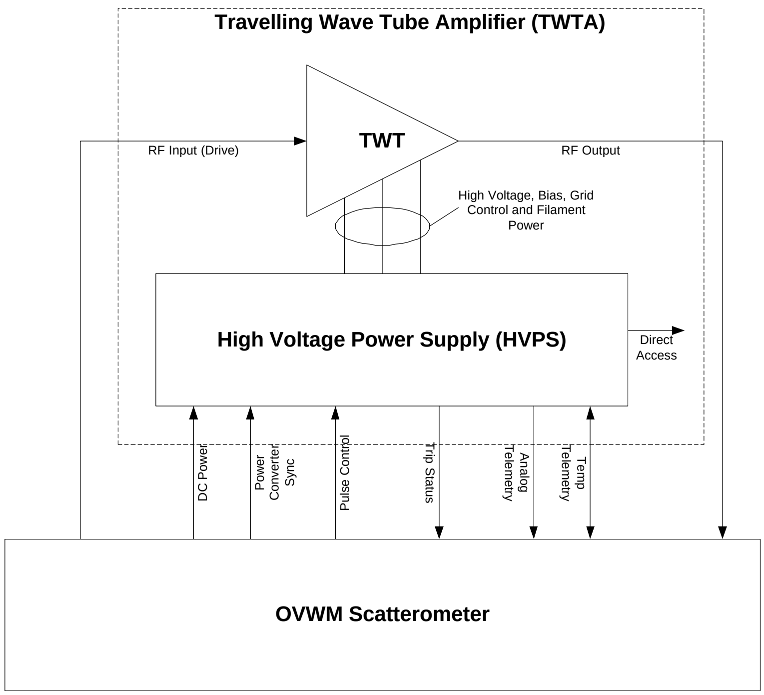


Figure 1 TWTA Functional Block Diagram

2.1.2. TWT Functions

The TWT provides Ku-Band signal amplification to the required output power level. The TWT controls the RF pulse by means of a beam-control electrode, nominally referred to herein as a "grid".

The TWT should not degrade with only the filament heater energized.

2.1.3. HVPS Functions

The HVPS provides the following functions:

- The TWTA start-up sequence, and applies voltages and currents as required.
- All of the appropriate regulated voltages and currents required by the TWT.
- Generates, for the TWT, the pulse-control (grid) high-voltage waveform in response to a low-voltage pulse control waveform supplied by the OVWM Scatterometer.

2.1.3.1. Self Protection Trip Function

The HVPS provides protection for the TWT and itself by means of a bus under- voltage trip circuit, a helix over-current trip circuit and an HVPS converter over- current trip circuit. These trip circuits disable all high voltages to the TWT. The trip function does not remove power from the TWT filament.

Following a protection trip, the HVPS automatically initiates a normal "Start up sequence" overriding any pulse control signal provided by the OVWM Scatterometer until TWTA is completed its normal start up sequence (warm up cycle).

2.1.3.2. Telemetry and Direct Access Functions

The HVPS provides the temperature, analog, digital, and status telemetry to the Scatterometer and a set of contractor selected Direct Access Signals for monitoring or trouble shooting during subassembly, subsystem, and spacecraft ground testing.

2.1.3.3. Synchronization of Power Converter

The internal clocks of the HVPS shall be synchronized to an externally supplied signal.

2.2. General Requirements

2.2.1. Conformance to Interface Control Drawing

The TWTA shall conform to an interface control drawing (ICD), generated by the contractor and approved by JPL. The ICD shall define all electrical, mechanical and thermal interfaces.

2.2.2. Mission Assurance

The design and construction of the TWTA shall be performed in accordance with an approved mission assurance plan.

2.2.3. Interchangeability and Replaceability

The TWTA shall be directly interchangeable in form, fit and function with other TWTAs of the same part number. Adjustment of RF Drive is permitted.

2.2.4. Useful Life

2.2.4.1. Operating Hours

The TWTA design shall satisfy all of its performance requirements for 70,000 hours operating lifetime.

2.2.4.2. Filament on/off Cycles

The TWTA shall be designed to survive 5000 TWT filament on/off cycles during flight operation and ground testing.

Note: It is expected that the TWT manufacturer can demonstrate 15000 filament on/off cycles on a device the design of which is representative of the OVWM TWT's cycling capabilities

2.2.5. Performance Requirements

The TWTA shall satisfy the performance requirements specified herein over all specified combinations of the following: DC input, RF input, RF load, operating time and environmental conditions.

2.3. RF Performance Requirements

2.3.1. Operating Frequency Range

The operating frequency range shall be from 13.352 to 13.452 GHz with a nominal band center frequency of 13.402 GHz.

The TWTA shall meet all performance requirements across the specified frequency band.

2.3.2. RF Input Power (RF Drive) Required for Saturation

2.3.2.1. Saturation Drive

At 25°C, the RF input power required to saturate the TWTA shall be between +0.00 dBm and +8.00 dBm.

2.3.2.2. Saturation Drive Variation

Over the Protoflight temperature range, the variation in the RF drive level required in order to saturate the TWTA shall be $\pm$1 dB, maximum.

2.3.3. TWTA Input and Output VSWR

The TWTA input and output ports shall each display a non-operating VSWR of 1.5:1 or less over the frequency range of 13.352 GHz to 13.452 GHz.

The TWTA input and output ports shall each display a non-operating VSWR of 2.0:1 or less over the frequency range of 13.152 GHz to 13.642 GHz.

2.3.4. Source and Load VSWR

The TWTA shall meet all performance requirements when operated with source and load impedance VSWR less than or equal to 1.1:1 at any phase angle and over the operating frequency range.

2.3.5. Pulsed RF Output Power

The TWTA shall produce a pulsed RF output controlled by a pulsed control signal supplied to the TWTA by the OVWM Scatterometer.

2.3.5.1. Peak RF Output Power Level

The peak saturated pulsed output power as measured at the output of the TWTA, shall be a minimum of 50.8 dBm (120 W) over the operating frequency range for the operating lifetime of the TWTA. Beginning of life saturated pulsed RF output power shall be consist with the end of life output power requirements.

2.3.5.2. Output Power Control - "Grid Step"

A control signal (often known as a "grid step") may be used to adjust the peak output power of the TWTA during its lifetime.

The TWTA shall not require changing the state of this control signal more than one time during the design lifetime.

2.3.6. Output Power Variations

The following output power variations shall be met throughout the operating frequency range after five (5) minutes of pulsed RF operation, over the entire specified lifetime of the TWTA.

2.3.6.1. Short Term Variation (30 seconds)

After 30 minutes of stabilization, the short-term variation in TWTA RF pulse amplitude shall be measured at a common point within each pulse. The common measurement point shall be after the pulse "overshoot" and associated "ringing", and shall be within the " flatness" duration as shown in figure 2. Over a period of 30 seconds, the amplitude of the RF pulse shall vary no more than 0.10 dB.

2.3.6.2. Maximum Variation Over the Frequency Band

The maximum saturated RF output power shall vary no more than 0.2 dB peak-to-peak over the operating frequency range assuming that temperature and drive power are held constant.

2.3.6.3. Drive Dependent Variation.

The power output of the TWTA shall vary no more than 0.2 dB when the RF drive is varied over the range of saturation drive $\pm$1.0 dB.

The power output of the TWTA shall not vary by more than 0.1 dB when RF drive is varied over the range of saturation drive $\pm$0.5 dB.

These variations assume constant temperature and frequency.

2.3.7. Pulse Control Signal Characteristics

The following paragraphs define the characteristics of the pulse control signal, which will be supplied by the OVWM Scatterometer to the TWTA.

2.3.7.1. Pulse Control Signal Form

The pulse control signal shall be a differential pair using a commonly used interface standard such as RS-422 or Low Voltage Differential Signaling (LVDS).

2.3.7.1.1. Line Receiver Termination

The differential line receiver(s) used shall be terminated appropriately for the interface used (e.g. 100 ohms for LVDS).

2.3.7.1.2. Common Mode Voltage

The differential line receiver shall tolerate, without damage or irreversible change in characteristics, application of any voltage up to and including the DC Bus supply voltage for a period of 1 hour.

The differential line receiver shall operate correctly with a common mode voltage from –0.7 VDC to 5.7 VDC.

2.3.7.2. Pulse Width

The TWTA shall support pulse widths of 0.5 millisecond to 2.0 millisecond. The nominal pulse width is 1.5 milliseconds.

2.3.7.3. Pulse Repetition Interval

The Pulse Repetition Interval (PRI), measured from rising edge to rising edge of the pulse control signal, will be specified at a value between 2.5 milliseconds to 6.7 milliseconds. The nominal pulse repetition interval will be 5.4 milliseconds.

2.3.7.4. Duty Cycle Limit

The TWTA shall meet all performance requirements over any combinations of pulse width and pulse repetition interval, as specified in the preceding paragraphs, up to 40%duty cycle (pulse width/ pulse repetition interval). The TWTA shall not be damaged, or suffer irreversible change, by any such combinations of pulse width and pulse repetition interval, between 40% and 80% duty cycle. In the range of 40% to 80% duty cycle, out-of-specification performance and even safe shut downs are acceptable.

2.3.8. RF Pulse Characteristics

The RF output power from the TWTA shall meet the requirements in the following paragraphs, assuming RF input at a level sufficient to saturate the TWTA, and Pulse Width, Pulse Repetition Interval, and duty cycle within the ranges previously specified. The RF characteristics are shown in figure 2.

2.3.8.1. RF Pulse Rise Time

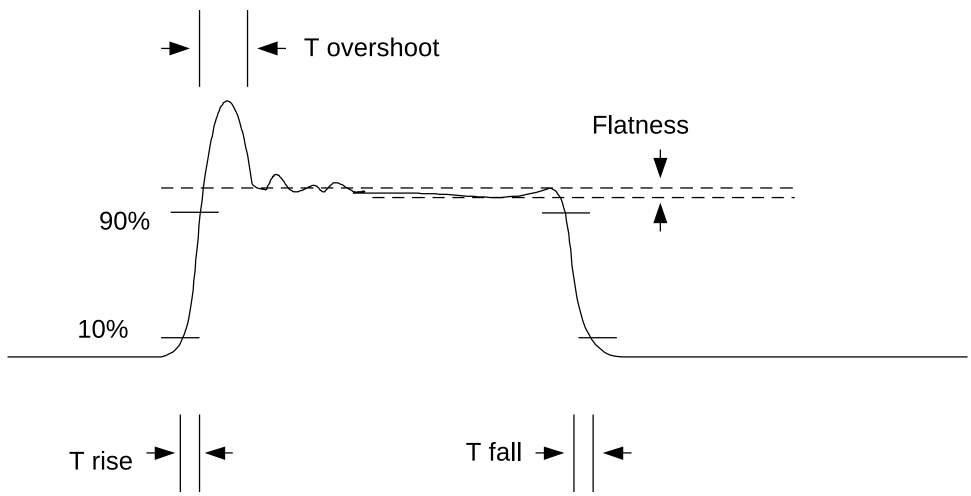


Figure 2 - RF Pulse Characteristics

The rise time (measured from 10% to 90%) of the RF output power, with constant RF input drive sufficient for saturated output, shall be no more than 1 microsecond.

2.3.8.2. Pulse RF Fall Time

The fall time (measured from 90% to 10%) of the RF output power, with constant RF input drive sufficient for saturated output, shall be no more than 1 microsecond.

2.3.8.3. Pulse Flatness

The RF output power during a pulse shall vary no more than 0.1 dB peak-to-peak.

2.3.8.4. Pulse Overshoot

Overshoot on the rising edge of the RF output pulse shall be no more than 1 dB and last no longer than 0.5 microseconds. [Jim Lux note: The intention of this requirement is to limit the energy error to less than 0.1% for the minimum pulse length (0.5 milliseconds).]

2.3.9. Control Signal – RF Output Timing Relations

The timing of the RF output power with respect to the pulse control signal is illustrated in Figure 3.

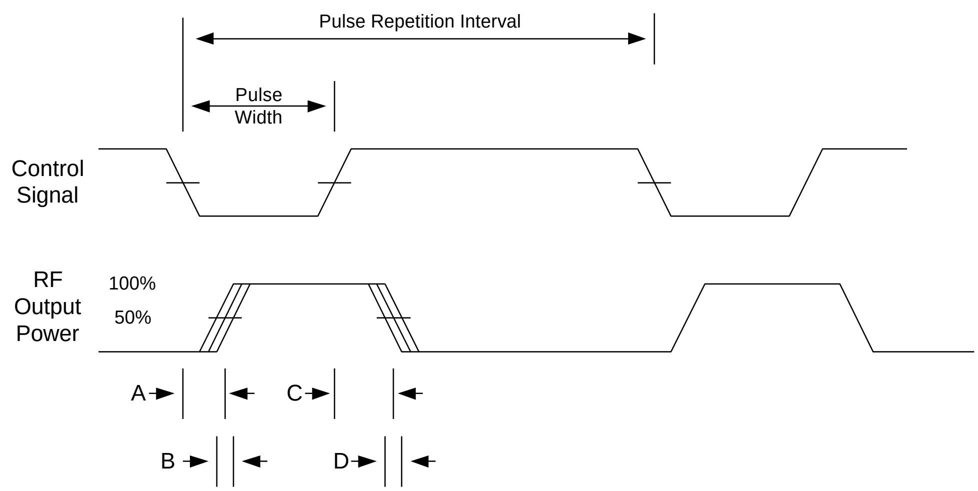


Figure 3 Timing Relationships

2.3.9.1. Pulse Control Signal Waveform

The OVWM Scatterometer will provide the TWTA with a pulse control signal conforming to the pulse width and PRI parameters defined above. A low voltage (logic “0”) shall represent the asserted condition where RF output power is present. A high voltage (logic “1”) shall represent the un-asserted condition where RF output power is not present. A disconnected condition on the input shall result in the “unasserted” state.

2.3.9.2. Turn On Delay Time

The average turn on delay time (A in Figure 3) shall be less than 5 microseconds.

2.3.9.3. Turn On Delay Time Variation

The variation in the turn on delay time (B in Figure 3) shall be less than 100 nanoseconds.

2.3.9.4. Turn Off Delay Time

The average turn off delay time (C in Figure 3) shall be less than 5 microseconds.

2.3.9.5. Turn Off Delay Time Variation

The variation in the turn off delay time (D in Figure 3) shall be less than 100 nanoseconds.

2.3.10. Spurious and Harmonic Output

2.3.10.1. Spurious Signal

No spurious output signal level of the TWTA shall be more than 0 dBm over the operating frequency range of 13.352 GHz to 13.452 GHz.

2.3.10.2. Harmonic Content

The output power of the second harmonic ($2f_0$) of the RF input frequency shall be less than 0 dBm.

The output power of the third harmonic ($3f_0$) of the RF input frequency shall be less than 25 dBm.

2.3.11. Output Noise Power Density

The output noise power spectral density over the operating frequency range shall not exceed -198 dBW/Hz in any 100 kHz band located within 5 MHz of center frequency with the pulse control de-asserted and RF input at a level sufficient for saturated drive.

With pulse control asserted and no RF drive, noise power density shall be less than - 110 dBW/Hz in any 100 kHz band located within 5 MHz of center frequency.

2.3.12. Unconditional Stability

The TWTA shall be unconditionally stable, and meet all applicable RF performance requirements under all RF drive conditions from no drive to 3 dB above saturated drive level.

The TWTA stability margin shall be demonstrated, without RF Drive applied, by terminating the TWT input and output into a short circuit of any phase angle, asserting the beam enable, and verifying that the TWT generates no spurious outputs, oscillations or instabilities.

RF output power versus RF input power curves shall have no discontinuity from -20 dB to +3 dB relative to saturated drive at frequencies of 13.352, 13.402 and 13.452 GHz.

2.3.13. Phase Shift – Group Delay

The change in phase of the TWTA output signal relative to the phase of the input signal at saturation drive and within its operating frequency range (13.352 to 13.452) shall not deviate from a straight line as a function of frequency by more than 5 degrees within any 2MHz band.

2.3.14. Voltage Breakdown

2.3.14.1. Breakdown Under Normal Operation Condition (hard vacuum and atmospherics)

There shall be no arcing, multipaction, or any other type of electrical breakdown in the TWTA circuitry during operation at atmospheric pressure less than or equal to 10^{-4} Torr. Hermetically sealed components shall not experience arcing, multipaction, or any other type of electric breakdown, even if seals are broken.

2.3.14.2. Breakdown Under Partial Vacuum

Under partial vacuum conditions, including critical pressure, no arcing multipaction or other type of electrical breakdown shall damage or create irreversible change to the TWTA. Electrical breakdowns shall not manifest themselves as currents on signal return line. Power supply outputs shall be self-limiting to prevent damage from excessive currents due to arcing or corona.

2.3.15. RF Breakdown Margin

The output structure of the TWT shall be capable of operation at 6dB over the saturated output power without arcing, corona breakdown or multipacting for any atmospheric pressure from 0 to 760 torr (0 to 1013 kPa).

2.3.16. No RF Drive

The operating TWTA shall withstand, without damage or irreversible change, operation without input RF drive for one hour, including start-up.

The TWTA shall be capable of pulsed operation with or without RF drive, up to and including 3.0 dB above the saturation drive level.

2.3.17. RF Overdrive

The operating TWTA shall withstand, without damage or irreversible change, a one (1) hour exposure to an RF input power of +6 dB relative to the saturation drive level.

2.3.18. RF Drive Transition During Beam-on Pulse

The TWTA shall withstand, without damage or irreversible change, transitions from no-drive to saturated drive and from saturated drive to no drive during the pulse.

2.4. Power Consumption

The TWTA shall consume no more than 120W DC power operating at saturated output power with a 40% duty cycle at 5.4 milliseconds Pulse Repetition Interval. At 40% duty cycle, the pulse width is 2.16 milliseconds.

The TWTA shall consume no more than 90W DC power operating at saturated output power with a 28% duty cycle at 5.4 milliseconds Pulse Repetition Interval. At 28% duty cycle, the pulse width is 1.5 milliseconds.

The TWTA shall consume no more than 20W DC power when the pulse control signal is de-asserted (no RF output).

2.4.1. Variable Pulse Width Power Consumption

The DC power consumption of the TWTA shall be measured at pulse widths of 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, and 2.0 milliseconds with a 5.4 millisecond PRI with the TWT and HVPS operating at the three stabilized temperatures specified in the Protoflight temperature requirements herein.

2.5. HVPS Requirements

The following requirements apply specifically to the HVPS

2.5.1. Gain and Phase Margin

All feedback loops shall have 35º/10 dB phase/gain margins to preclude oscillation. The phase/gains margins shall be met under all conditions, including warm-up-beam-on, beam-off, no RF drive, and saturated drive.

2.5.2. Tolerance of Arcs, Stored Energy

The HVPS shall be able to withstand any TWT arc(s) without damage or degradation.

2.5.3. Converter Synchronization

The HVPS converter shall be synchronized to an externally supplied signal at 500 kHz (+/- 10%) with peak-to-peak amplitude of 1 Volt. The synchronization input shall be AC coupled.

2.6. 28 V POWER BUS

All DC power for the TWTA will be derived from the 28 V bus. The TWTA's bus characteristics are described below. On/off switching of the TWTA will be by application and removal of bus power. The power bus/TWTA interface is shown in Figure 1.

2.6.1. Bus Source Characteristics

2.6.1.1. Bus Voltage

The normal operating range of DC bus voltage will be 24-32 V.

2.6.1.2. Bus Source Impedance

The bus source impedance will not exceed the following limits:

- DC – 20 kHz <0.17 ohms
- 20 kHz – 1 MHz +6 dB/octave

2.6.1.3. Bus Voltage Transients

The bus input power transient to the TWTA will not exceed +/- 4V, 3 milliseconds wide. The TWTA shall operate through this input power transient if it occurs.

2.6.1.4. Anomalous Voltage

Under an anomalous condition of an instantaneous16 volt drop in the DC bus voltage for a period of up to 5 milliseconds caused by other equipment anomalies, the TWTA shall not be damaged or suffer an irreversible change in operating characteristics.

2.6.2. Bus Return

The bus return shall be isolated from chassis as described later in "Ground and Return Isolation".

2.6.3. Undervoltage Protection

The TWTA shall not be required to maintain the DC power consumption limits or other performance specifications when the bus voltage is outside the normal operating range (24-32 Vdc).

The TWTA shall trip when the bus input voltage to the TWTA drops below 22.0 V $\pm$ 0.5 V. The undervoltage trip shall not respond to undervoltage conditions with a duration less than 70 microseconds. The TWTA shall initiate a start-up sequence when the bus input voltage rises above 23.5 V.

2.6.4. DC Input Filter

Any filtering to meet this specification shall be implemented between power and power return, and not between power lines and chassis.

2.6.5. Rate-of-Change of TWTA Input Current and Inrush Current Limit

The TWTA turn-on shall be controlled by the HVPS such that its rate-of-change of input current di/dt, at turn-on shall be less than 0.15 amp/microsecond. The peak inrush current during turn-on shall not exceed 7A.

2.6.6. TWTA Induced Reverse Bus Current

The TWTA shall not induce more than 100mA reverse current flow into the power bus when the power bus is switched.

2.6.7. TWTA Induced Reverse Bus Voltage

The TWTA shall not induce a reverse transient voltage on the power bus that exceeds 10 V below to the power bus return.

2.6.8. Input Filter Resonant Frequency

The resonant frequency of the TWTA DC input filter shall not exceed 20 kHz, exclusive of parasitic resonance, when measured at the TWTA input terminals.

2.6.9. Over Voltage Protection

The TWTA shall not be damaged or suffer irreversible changes in operating characteristic by application of input voltages up to 36 V for 1 hour.

2.6.10. Power Removal

The TWTA shall survive, without degradation or irreversible change in operating characteristics, the sudden removal of power.

2.7. Grounding and Returns

The HVPS shall have different returns for each of the circuits or groups of circuits as described in the following paragraphs. The different returns shall be isolated from each other.

2.7.1. 28 V Bus Return

The bus return shall be used for all DC supply current drawn from OVWM Scatterometer.

2.7.2. Temperature Telemetry Returns

Each temperature transducer shall have a separate return.

2.7.3. Analog Telemetry Return

The analog telemetry shall be isolated from all other grounds. These circuits shall be powered by an isolated power supply so that they can be connected to the analog telemetry ground of the OVWM Scatterometer.

2.7.4. Digital Telemetry and Control Return

The digital telemetry and command signal circuits shall be isolated from all other grounds. These circuits shall be powered by an isolated power supply so that they can be connected to the digital ground of the OVWM Scatterometer.

2.7.5. Power Converter Synchronizing Signal Return

The power converter synchronizing signal return shall be common with the chassis ground.

2.7.6. Direct Access Returns

The Direct Access returns shall be assigned at the designer's discretion but shall not compromise the TWTA grounding requirements.

2.7.7. Chassis Ground

Chassis ground shall be tied to the amplifier case (TWT and HVPS chassis). This ground shall also be the RF signal ground.

2.7.8. Ground and Return Isolation

The analog and digital telemetry returns shall be electrically isolated from the bus return and chassis ground by 1 megohm minimum, shunted by 200 pF maximum. All other returns within the HVPS except the direct access returns shall be electrically isolated from chassis ground and bus return by at least 1 megohm, shunted by less then 600 nF.

2.8. Junction Temperature Limits

The HVPS shall be designed such that power Schottky rectifier junction temperatures shall not exceed 95°C and all other semiconductor device junction temperatures shall not exceed 110°C when the heatsink temperature is less than or equal to +70°C (worst-case).

2.9. Protection (Trip) Circuits

Trip circuitry shall be provided for each of the specified faults. The circuitry shall protect the TWTA and the spacecraft in the event of faulty operating conditions, as addressed below. If any trip condition occurs, the high voltages shall be removed, the filament power shall not be removed, and the turn-on sequence initiated.

2.9.1. Helix Current Trip

The TWTA shall trip as specified when the TWT helix current exceeds safe values. After tripping, the TWTA shall initiate a start-up sequence. During the shutdown period the TWTA shall indicate status as Helix Current Trip.

2.9.2. Bus Under Voltage Trip

The HVPS shall detect a bus undervoltage condition and trip as defined herein.

The TWTA shall initiate a start-up sequence when the bus input voltage returns to normal. During the shutdown period the TWTA shall indicate status as Under Voltage Trip.

2.9.3. Converter Current Trip

The TWTA shall trip as specified when the high voltage converter current exceeds safe value. The TWTA shall initiate a start-up sequence. During the shutdown period the TWTA shall indicate status as Converter Trip.

2.10. Telemetry

The TWTA telemetry circuits shall generate voltages, which shall allow determination of the condition of the TWTA at any time. All telemetry circuits shall reside within the HVPS.

Table I is a list of all telemetry signals. They will be grouped into 3 categories, analog, temperature and status signals.

Table I - Telemetry Signals

Telemetered Parameter	**Parametric Characteristics**	**Telemeter Parameter Range**
Helix Current Trip Status	Normal Operation or Trip	Logic level high = Trip
TWTA Converter Current Trip Status	Normal Operation or Trip	Logic level high = Trip
Bus Under voltage Trip Status	Normal Operation or Trip	Logic level high = Trip
TWT Helix Current	Contractor Defined	1 to 4 Volts (analog)
Beam Control Voltage	Contractor Defined	1 to 4 Volts (analog)
Bus Current	Contractor Defined	1 to 4 Volts (analog)
TWT Temperature	-40 to 100°C	420 to 700 O (temp)
HVPS Temperature	-40 to 100°C	420 to 700 O (temp)

2.10.1. Redundant Telemetry Circuits

Each telemetry circuit shall be duplicated, providing two independent identical outputs for each circuit. The failure of one circuit shall not affect the function of the redundant circuit.

2.10.2. Output Voltage Limits

Telemetry channel outputs shall not exceed 5.7 Volts or fall below –0.7 Volts as the result of any single failure.

2.10.3. Telemetry Channel Failures

Failure of any telemetry circuit or interface shall not degrade the performance of the remaining TWTA interfaces. A failure in a monitoring circuit shall not degrade the function being monitored or impact TWTA reliability. Failure of Scatterometer telemetry receiver shall not degrade the performance of the TWTA or any of its telemetry circuits.

2.10.4. No Damage From Shorts to Ground Returns

The TWTA shall not be damaged or suffer irreversible change as the result of shorting any telemetry output to any ground return.

2.10.5. Analog Telemetry Characteristics

Analog telemetry signal outputs shall range from 1 to 4 Volts and shall use the command and telemetry connector. Parameter range endpoints, as listed in Table I, shall include all variations of the parameter due to normal operation, temperature effects, and aging effects. The channel outputs shall be referenced to the analog voltage telemetry return.

2.10.5.1. Channel Calibration.

Calibration curves of each channel output versus parameter input shall be provided at -20°C, -5°C, +35°C, +55°C, and +75°C.

2.10.5.2. Channel Accuracy.

The output of each telemetry channel shall represent the parameter being monitored to within 5.0% of full scale at the time of calibration.

2.10.5.3. Channel Source and Load Impedance.

Analog telemetry circuits shall have a source impedance of 5 ±1 k ohms. They shall operate into a load impedance greater than 100 k ohms, but shall not be damaged when operated into 0 ohms for indefinite periods.

2.10.5.4. Channel Isolation

Analog telemetry signals supplied to the telemetry connector shall be isolated from each other by ≥ 1 kilo-ohms.

2.10.5.5. Feedback Current Immunity

The analog telemetry channels shall withstand a 1.0 mA maximum feedback current into the source in the event of a C&DH failure.

2.10.5.6. TWT Helix Current

The TWT helix current shall be measured by generating a DC voltage. The DC voltage shall be proportional to the helix current during the RF pulse. The worst-case projected helix current telemetry voltage shall occupy no less than 85% of the available voltage range (1 to 4 V).

2.10.5.7. TWT Beam Current Control Voltage

If TWT Beam current control is used, a telemetry output shall be provided which shall indicate a change in control electrode voltage.

2.10.5.8. TWTA Bus Current

The TWTA power bus input current shall be measured by generating a DC voltage, which is proportional to the bus current and shall occupy no less than 85% of the available voltage range (1 to 4 V).

2.10.6. Temperature Telemetry

The TWTA shall use JPL-supplied temperature sensors to provide temperature telemetry for the TWT and HVPS. Temperature transducers will have nominal 500-Ohm impedance at 0°C and approximately 2 Ohm/°C sensitivity. They will be driven by externally supplied 1 mA currents, to generate telemetry voltages, which are proportional to temperature. TWT baseplate temperature shall be measured at the collector end of the TWT. There shall be two temperature transducers for the TWT and two for the HVPS.

2.10.7. TWTA Digital Status Signals

The TWTA shall provide the bi-level status signal of Table I.

2.10.7.1. Signal Level Definition

A no-trip condition shall be indicated by a signal between -0 V and +0.4 V. A trip condition shall be, indicated by a signal between +4.1 V and +5.6 V. For any bus voltage below 18 V, the telemetry outputs need not meet the above requirements.

2.10.7.2. Channel Source Impedance.

Digital Status telemetry output source impedance shall be less than 750 ohms at the 5V state and less than 1500 ohms in the 0V state.

2.10.8. Direct Access

Direct access to selected nodes within the HVPS circuits will be provided for test purposes. The direct access lines shall be terminated at a special direct access connector. A resistor of at least 10kO shall be incorporated with each line such that a short between any direct access line and any part of the circuit or to chassis shall not result in TWTA performance degradation. Direct Access functions and their interface to the support equipment shall be defined by the contractor. All direct access functions shall be referenced to a direct access return(s).

3. Connectors

No contact shall carry more than 1 A. Spare contacts in any connector shall be left unwired. All connector shells shall be tied to the chassis ground

3.1. Power Connector

A male connector, selected as appropriate by the contractor, shall be used for power.

3.2. Command and Telemetry Connector

A female connector, selected as appropriate by the contractor, shall be used for telemetry and mode control.

3.3. Direct Access Connector

A female connector, selected as appropriate by the contractor, shall be used to permit convenient monitoring of the amplifier functions.

3.4. RF Connectors

3.4.1. RF Input

The connector for RF input shall be SMA (female) MIL-C-39012/SMA.

3.4.2. RF Output

The connector for RF output shall be a WR-62 waveguide flange.

4. TWT/HVPS Connections

4.1. Cable Length

The cable between the TWT and HVPS will be between 0.5 and 1.5 meters long.

4.2. Shielded Harness

All electrical connections between the TWT and the HVPS shall be made through a shielded harness.

5. Burn-In

TWTA and its subassemblies shall accomplish burn-in as outlined in succeeding paragraphs.

5.1. HVPS Burn-in

Prior to final TWTA integration, the HVPS, in its final configuration (less TWT), shall complete a minimum of 168 hours burn-in. This burn-in shall occur while the HVPS base plate at 55°C and supplying rated power to a load simulating the TWT.

5.2. TWT Burn-in

The TWT, prior to integration with the HVPS, shall complete 750 hours of burn-in, while operating at a 40% duty cycle with saturated RF output power.

5.3. TWTA Burn-in

The TWTA, in its final configuration, shall be subjected to a 500 hours failure free burn-in at a base plate temperature of 30 $\pm$ 5.0 degrees C.

6. Environmental Design Requirements

The TWTA shall be designed to operate over all combinations of the environmental conditions stated herein. The following is a summary of these requirements.

6.1. Ground Operations, Container and Handling Environment

6.1.1. Temperature and Pressure Environment

The TWTA ground handling temperature and pressure environment shall be restricted between 5°C to 45°C and 520 Torr to 760 Torr, respectively.

6.1.2. Humidity Environment.

The TWTA ground-handling relative humidity environment shall be restricted between 30% and 70%. While in a shipping container, the HVPS shall be wrapped in a non-ESD-generating vapor barrier with redundant maximum humidity indicators.

6.1.3. Shipping and Transportation.

The TWTA shipping containers shall be designed in such a manner to ensure safe delivery at JPL or a designated system contractor, per JPL SeaWinds Environmental Requirements-part1: Environmental Design Requirements (D - 10958) and D- 8208 requirements. The TWTA shipping containers shall use load-monitoring devices to ensure safe load limits are not exceeded.

6.2. Space Environmental Design Requirements

6.2.1. Temperature Limits.

The temperatures given in the following table, except where otherwise indicated, refer to the temperature of an isothermal base plate(s) on which the TWT and HVPS are mounted, per the contractor's recommended method.

	HVPS		TWT	
	Cold	Hot	Cold	Hot
Allowable Flight Temperature (AFT)	0°C	45°C	0°C	45°C
Flight Acceptance (FA)	-5°C	55°C	-5°C	55°C
Qualification/Protoflight (PFM)	-20°C	75°C	-20°C	75°C
Design Verification	-30°C	85°C	-30°C	85°C

The design verification temperature range shall be used for worst-case analysis only, not for hardware testing. The TWTA shall meet the performance requirements of section 2.0 herein over the entire qualification temperature range.

6.2.2. Temperature Dwells

The sum of the hot dwell times shall be 144 hours. The sum of the cold dwell times shall be 24 hours

6.2.3. Temperature Transitions

Short-term temperature transitions shall not exceed 3°C per minute; the average temperature transitions must not exceed 60°C per hour.

6.2.4. Thermal Vacuum Profile

Figure 4 shows the Thermal Vacuum test profile for Qualification and Protoflight (PFM) testing.

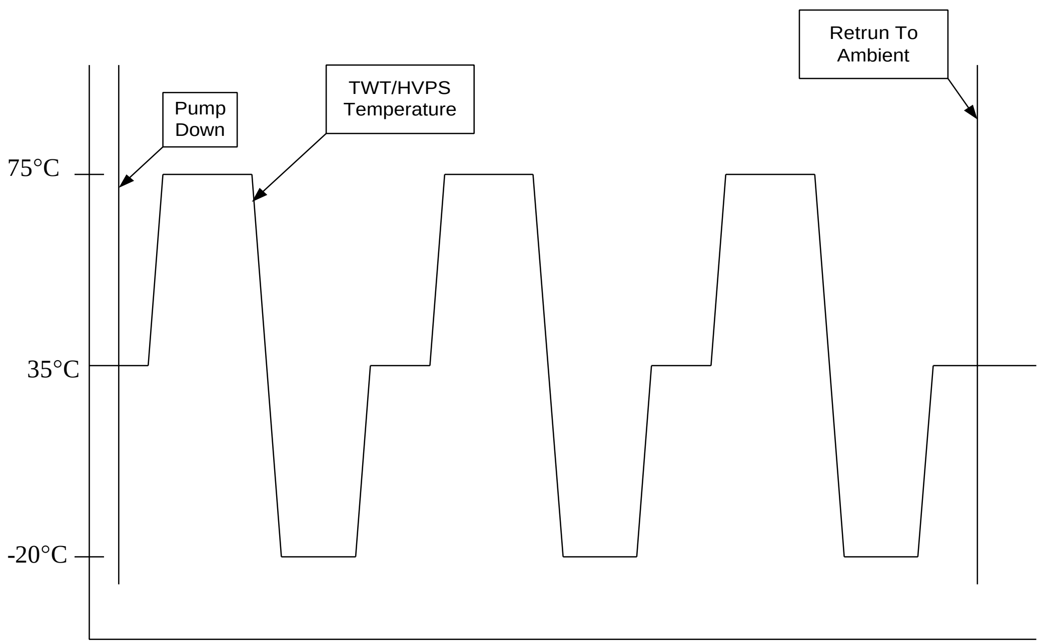


Figure 4 – Thermal Vacuum Test Profile

6.2.4.1. Consistency of Thermal Vacuum Transitions

Temperature transitions during thermal vacuum testing shall be consistent with each other. Each transition shall be at the same rate as other transitions between the same temperatures.

6.2.5. Pressure Decay

The TWTA shall be designed to withstand a maximum rate of pressure change of 70 Torr/second for a period not less than 10 seconds.

6.2.6. Vacuum

The TWTA shall meet the performance requirements of this specification at ambient for all pressures between 760 Torr and $1x10^{-5}$ Torr. During pressure transitions the TWTA shall operate without damage or degradation.

6.2.7. Thermal Vacuum

TWTA performance according to specification shall be verified in a vacuum at specified temperatures. The thermal vacuum test shall be conducted at a pressure of less than 10^{-5} Torr. The operating TWTA shall be tested to the profile shown in Figure 4 for the Qualification unit and Protoflight unit. During the test, the environmental conditions versus time shall be recorded and TWTA performance shall be monitored and recorded as shown in verification matrix Table IX.

6.2.8. Random Vibration

The non-operating TWT and HVPS shall be designed to withstand the random vibration requirements (acceleration spectral density or slope) per Table II, as applied to the HVPS and TWT assembly mounting points in each of the three mutually orthogonal axes.

Table II **-** Random Vibration Profile

Frequency Range	Acceleration Spectral Density or Slope	
(Hz)	Flight Acceptance	Qualification/Protoflight
20-40 40-1500 1500-2000	+6 dB/octave 0.1 g^2/Hz -9 dB/octave	+6 dB/octave 0.2 g^2/Hz -9 dB/octave
Overall	13.4Grms	19.0Grms
Test Duration: 2 minutes per axis for Qualification 1 minute per axis for Flight Models and Protoflight Models Test Tolerance: +3 dB in Spectral Levels +1 dB in Overall Levels		

The TWTA shall be unpowered during qualification/Protoflight level vibration testing. The levels shall be applied at the TWTA mounting points in each of the three mutually orthogonal axes.

6.2.9. Structural Resonance

The TWTA shall be designed to have no sinusoidal resonant modes below 200 Hz.

6.2.10. Pyrotechnic Shock

The operating TWTA shall be designed to withstand the pyrotechnic shock spectra shown in table III and plotted in Figure 5. The shock response spectra (SRS) shall be applied separately at the TWTA mounting points in each of 3 orthogonal axes. The shock spectra shall consist of exponentially decaying sinusoidal with approximately 20 ms decay time. The design qualification test shall consist of two such shocks.

Table III - External Pyroshock Environment

Frequency, Hz	SRS Level
100-1000	+12 dB/octave
1000-10000	2000 g

Note: SRS (Q=10)

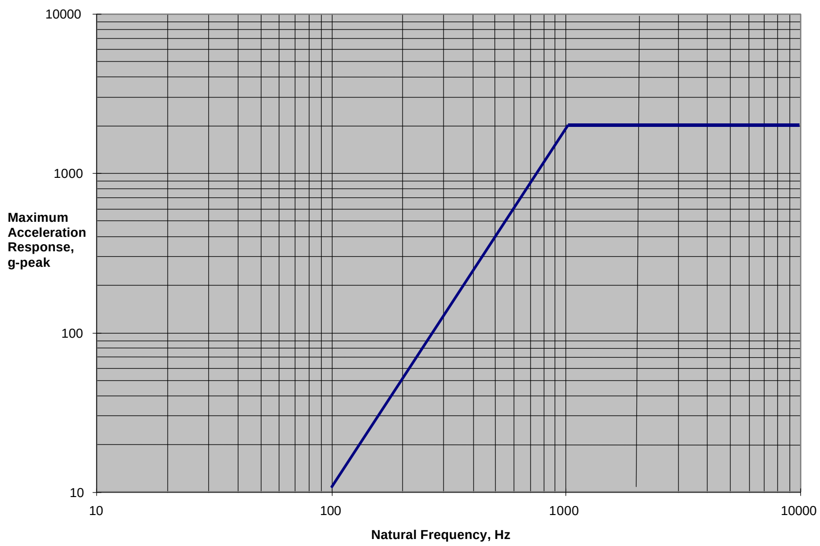


Figure 5- Pyroshock Environment Spectrum

6.2.11. Radiation Hardness

The TWTA shall be designed to function within specification during and after exposure to total ionizing dose of 25 kRad.

6.2.12. Internal Charging

For ESD protection, all metallic elements used in association with the TWTA electronic design, including wires, unused conductors, radiation shields, and circuit board traces shall have a conductive path to chassis ground with a resistance less than 10^8 ohms when measured in air and 10^{12} Ohms when measured in vacuum. Non-conductive surfaces, which can store more than 3 mJ of electrostatic energy, shall not be used. All conductive materials in the TWTA with resistance less than 10^8 Ohms and with a surface area greater than 2.0 cm^2 shall be electrically connected to chassis ground with a resistance less than 0.1 Ohms.

6.2.13. Electromagnetic Compatibility Design Requirements

The TWTA shall meet the requirements as specified below. For reference use MIL-STD-461C and –462- for the appropriate test setup. All EMC tests shall be performed using the spacecraft power supply simulator circuit as shown in Figure 6.

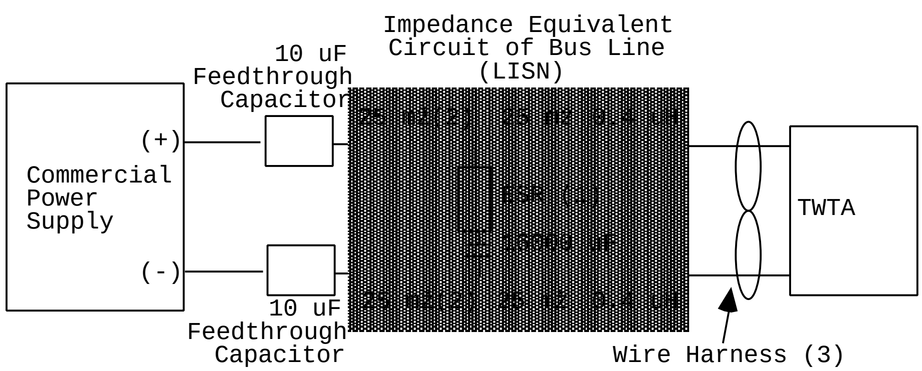


Figure 6 **-** Line Impedance Simulation Network (LISN)

Notes to Figure 6:

1. Equivalent Series resistance (ESR) is smaller than 50 mΩ.
2. Value when the impedance of cable between commercial power supply and LISN can be negligible. If this impedance can't be negligible, 50 mΩ shall be provided
3. A wire harness 1 meter long (or other length as mutually agreed between JPL and contractor) shall be used.

6.2.13.1. Power Line Conducted Emission Ripple

The following paragraphs specify the requirements for Noise Current and Noise Voltage on Power Lines.

6.2.13.1.1. CE01/03 Noise Current on Power Lines

CE01/03 applies to power leads over the frequency range of 0.1Hz to 100 MHz. This applies to the active and return lead separately. The narrowband current emissions including ripple and repetitive transients shall meet the requirements as graphically illustrated in figure 7.

- Shall not exceed 3% peak-to-peak of primary input current at steady state over a frequency range of 0.1 Hz to 20 kHz.
- Shall decrease at 6 dB per octave from 20 kHz over a frequency range of 20 kHz to 100 MHz; however, the limit shall not be lower than 30 dBμA (rms).

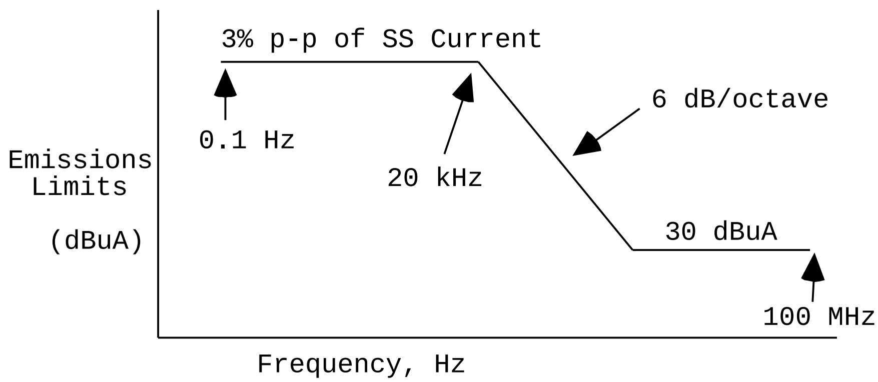


Figure 7 – Noise Current on Power Lines Emissions Limit

6.2.13.1.2. Conducted Emissions (CE06)

CE06 applies to RF energy measured at the transmit terminal (or waveguide) of the TWTA while it is operating normally. The applicable frequency range shall be up to 100 GHz. All emissions, harmonic or other spurious expect for the second or third harmonic, shall be 80 dB below the fundamental frequency. The second and third harmonic shall be below -30 dBc. Above 40 GHz measurement is preferred, but verification may be analysis.

6.2.13.1.3. Noise Voltage on Power Lines (CE11)

Ripple voltage fed back on the power bus shall not exceed 1 mV zero-to-peak per 1 Watt of power consumption (steady state) for powers above 10 W. If power consumption is less than 10 W, the limit is 10 mV zero-to-peak. Measurement frequency range shall be DC through 10 MHz. Voltage spikes (transients) are not included in this requirement.

6.2.13.2. Conducted Susceptibility Ripple (CS01, CS02)

CS01/02 applies to power leads over the frequency range 0.1 Hz to 100 MHz. It is a differential voltage ripple applied to the existing power so that the ripple causes the power voltage to fluctuate above and below the nominal line voltage. The TWTA shall continue to operate within specification while ripple voltage is swept over the frequency range at a rate of less than one minute per octave. The operation and performance of the OVWM TWTA shall not be degraded when the following voltage is injected into the main power bus.

Waveform	Sinusoidal
Frequency Range	0.1 Hz - 100 MHz
Voltage	1 V_{P-P}

6.2.13.3. Conducted Susceptibility Transients (CS06)

The OVWM instrument shall meet the performance requirements when the following noise is superimposed on the primary power bus, for voltages between 24 and 32 V at the TWTA interface point. The repetitive pulse consists of:

- Alternate +6V and -6V transients
- Each pulse is 2 ms wide
- All rise and fall times are less than 1 µs
- The double pulses repeat at a 2 pps rate
- The space between the + and - pulses is undefined

Figure 8 illustrates this transient pulse train.

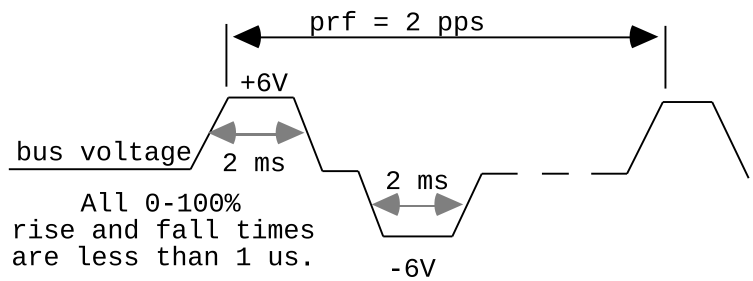


Figure 8 - Transient Pulse Train

Voltage may be limited so that the transient pulse does not exceed 3 amperes above or below the nominal line current.

6.2.13.4. Radiated Emission Low Frequency Magnetic Field (RE01)

AC magnetic field emissions shall comply with the following equations when measured at seven centimeters (7 cm) from any box surface or cable surface:

1) 30 Hz to 30 kHz: 79.1 - 40.01 log f (dBpT) {f in kHz}

2) 30 kHz to 50 kHz: 20 dBpT

This is illustrated in Figure 9. This requirement applies to OVWM Protoflight hardware, cables, and interconnecting wiring, but not to radiation from the antenna. Included are the fundamental frequencies, as well as all spurious emissions, including harmonics.

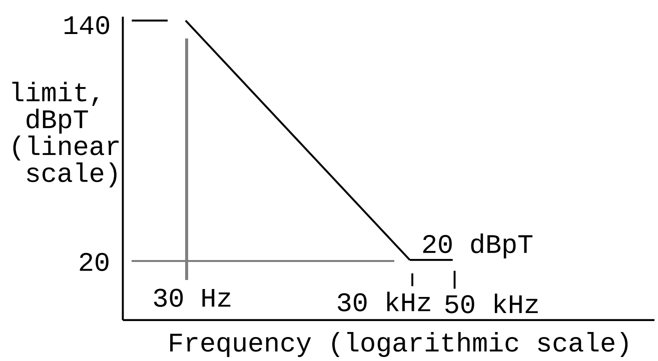


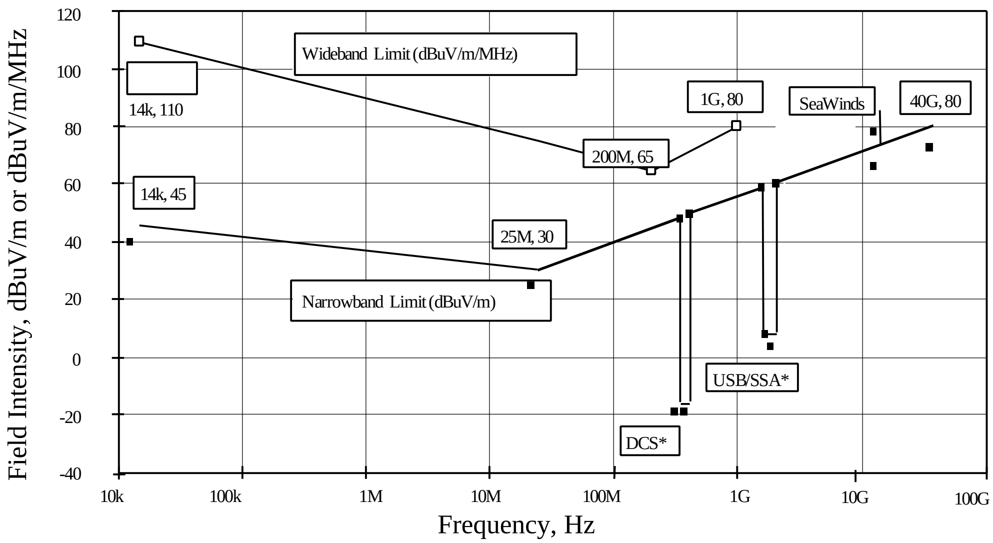
Figure 9 - Radiated Emission Low Frequency Magnetic Field Limit

6.2.13.5. Radiated Emission (RE02)

OVWM hardware shall comply with the normal narrowband and broadband electric field radiated emissions limits shown in Figure 10, as well as the restricted narrowband limits shown in Table IV. Above 30 MHz, the limits shall be met for both horizontally and vertically polarized waves. The measurement distance shall be one meter (1m) from the surface of the OVWM instrument.

This requirement applies to OVWM Protoflight hardware, cables, and interconnecting wiring, but not to radiation from antennas. Included are the fundamental frequencies, as well as all spurious emissions including harmonics.

The broadband requirement applies to all switching transients resulting from automatic cycling of electronic switching circuitry, pulsing in response to the pulse control signal, and manual switching.



(*See Table IV for the Restricted Narrow Band Regions)

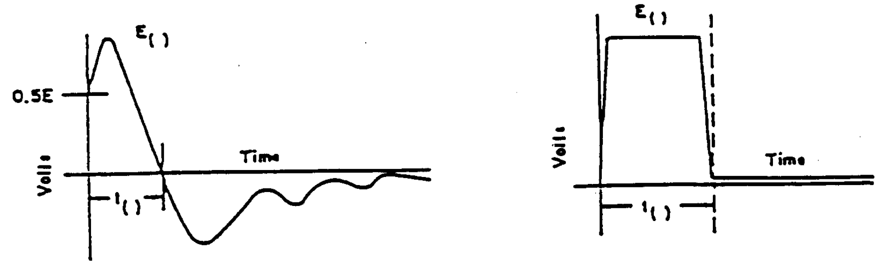
Figure 10 Radiated Emission Limits

Table IV - Radiated Emissions, Restricted narrow Band Regisons

Allowable Emission Levels		
Frequency Range, MHz	Allowable Level, dBμV/m	Note (Reference)
	TWTA	
375 - 385	46	DCS receiving frequency
385 - 396	31	
396 - 401.5	6	
401.5 - 401.6	-14	
401.6 - 401.7	-16	
401.7 - 401.8	-14	
401.8 - 406	6	
406 - 411	31	
1994 - 2034	36	USB/SSA receiving frequency
2034 - 2054	11	
2054 - 2094	36	

6.2.13.6. Radiated Susceptibility, Electric Field (RS02)

The TWTA shall be subjected to the spikes with the waveforms shown in Figure 11 and with the specified voltage and pulsewidth, in accordance with MIL-STD-461, Part 3: RS02; and shall perform per specification during those exposures.



E( ) = 200 V
T( ) = 10 µsec ± 20%
Spike Number 1

E( ) = 200 V
T( ) = 0.15 µsec ± 20%
Spike Number 2

Figure 11 - Radiated Susceptibility, Electric Field

6.2.13.7. Radiated Susceptibility

The TWTA shall perform per specifications when irradiated with any of the electric field strengths of Table V.

Table V - Radiated Susceptibility, Electric Field

Frequency Range	Field Strength (V/m)	Emission Source
Overall Emission Regions:		
14 kHz - 30 MHz	10	
30 MHz - 10 GHz	5	
10 GHz - 40 GHz	20	
Particular Emission Regions:		
467.7 MHz + 56 kHz	19	DTL
465.9875 MHz ± 27 kHz 468.875 MHz ± 27 kHz	20	DCS
2220 MHz + 1.75 MHz	NR	USB/SSA
8150 MHz + 31 MHz	6	DT (X1)
8350 MHz + 6.5 MHz	NR	DT (X3)
13.402 GHz + 1.8 MHz	N/A	OVWM*
* 25.8505 GHz + 68 MHz	NR	KSA

*Center frequency varies ± 734 kHz and the 90% bandwidth is ±40 kHz

NR: No particular emission region requirement. (Overall Emission Region Requirement applies).

Above 30 MHz, these requirements shall be met for both horizontally and vertically polarized waves.

6.2.14. Magnetic Field, Design Requirements

6.2.14.1. Magnetic Field Susceptibility

The TWTA shall continue to operate within specifications while a DC magnetic field is applied to the TWTA as great as 5×10^4 nano Tesla to 27 nano Tesla from any direction.

6.2.14.2. Magnetic Field Emissions

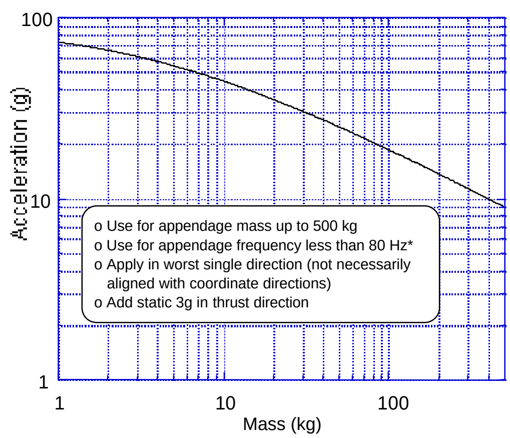
The TWTA shall be designed so that its DC magnetic field shall be less than 200 nano Tesla when measured at one meter away from the center of the TWTA Box, while operating or non-operating.

6.3. STRUCTURAL DESIGN

6.3.1. Limit Loads

The TWTA enclosure structures and their mounting interfaces shall be designed to the limit loads defined in Figure 12 Mass Acceleration Curve (MAC).

The MAC limit load factors, which are based on the total mass of each subsystem, will be applied at the center of gravity of each subsystem in their launch configuration, and in the direction yielding the most critical loads. In lieu of knowledge of the most critical direction, it is acceptable to apply the MAC limit load factor in three orthogonal directions separately.



* Items with small mass and high frequency shall be verified with random specification

Figure 12: Preliminary Mass Acceleration Curve for OVWM Project

6.3.2. Strength

6.3.2.1. Materials

The TWTA shall use property data, for all allowable materials, obtained from the most recent revision of MIL-HDBK-5F, "Metallic Materials and Elements for Aerospace Vehicle Structures," or from other sources approved by the JPL cognizant engineer(s). Type "A" basis material properties (99% probability and 95% confidence) or equivalent shall be used for all primary support structures.

6.3.2.2. Factor of Safety

The TWTA shall be designed with a yield factor of safety (FS) of 1.6 and an ultimate of 2.0 for primary and secondary structures.

6.3.2.3. Margins of Safety

The margins of safety of all the TWTA structural elements shall be positive (greater than or equal to zero) and shall be calculated as:

$$\text{Margin of Safety} = \frac{\text{Allowable Load/Stress (yield or ultimate)}}{\text{Applied Load/Stress X FS (yield or ultimate)}} - 1 \geq 0$$

6.3.3. Fatigue, Thermal Effects, and Non-linearity

6.3.3.1. Fatigue

Fatigue shall be considered in the design of the TWTA structural elements Material selection shall consider fatigue characteristics in relation to the design requirements of the structural elements. A safety factor of 4.0 or greater shall be used in life.

6.3.3.2. Thermal Effect

Thermal stresses and thermal distortions shall be considered in the analysis of structures. Thermal conditions, such as temperature and thermal gradient extremes, which could affect latch loads and/or structural alignments shall be analyzed or tested. Consideration shall also be given to deterioration of material properties caused by temperature changes. Previously stated yield and ultimate margins of safety shall be positive with thermal effects included.

6.3.3.3. Structural Non-linearity

Any significant structural/mechanical nonlinear characteristics shall be thoroughly investigated by analysis and/or test.

6.4. Mechanical Requirements

TWTA mechanical design shall comply with the requirements of JPL D 8208 or JPL-approved equivalent and this document. Figures 13 and 14 provide a nominal Mechanical Interface Layout describing the desired dimensions, mass, and thermal interface.

6.4.1. Dimensions

TWTA shall be designed for minimum size without sacrificing reliability. Final dimension shall be established at the start of design. It is desired that the HVPS and TWT fit within the maximum envelope shown in Figure 13 and 14.

6.4.2. Mass

Total mass of the TWTA, including TWT/HVPS cable, but excluding mounting hardware, shall be less than 3.3 kilograms.

6.4.3. Identification and Marking

TWTA shall be marked as identified per JPL- approved configuration plan. All internal assemblies shall be marked and identified in accordance with the JPL- approved configuration plan.

6.4.4. Connector Accessibility

All TWTA connectors shall be placed to facilitate ease of interconnections and subassembly replacement.

6.4.5. Venting

The pressure reduction shall be continuous in the range of one atmosphere to 10% of atmosphere. The TWTA shall be vented to survive critical pressures encountered during launch or normal operation,

6.4.6. Cooling

Conduction through the base plate shall be the primary means of heat removal from the TWTA. Cooling shall be conduction through the mounting plate and shall not rely on radiation or convective cooling.

Finish

The external finish shall be specified in a contractor generated ICD and shall meet the out-gassing requirements in accordance with D - 11151.

All TWTA external surfaces shall be designed to be cleaned with isopropyl and/or ethyl alcohol.

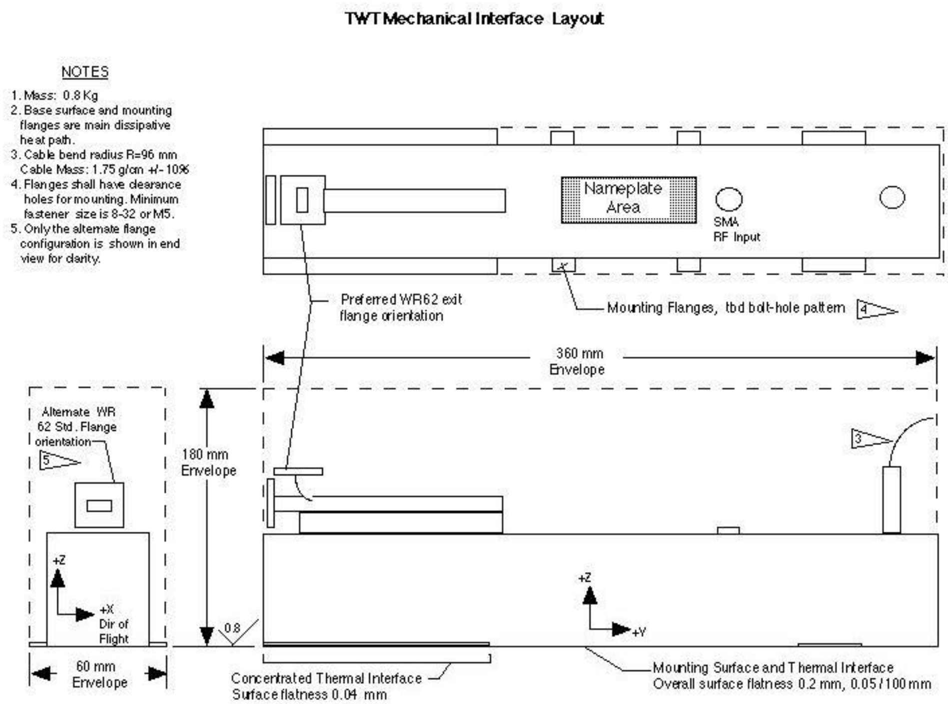


Figure 13 - TWT Mechanical Interface Layout

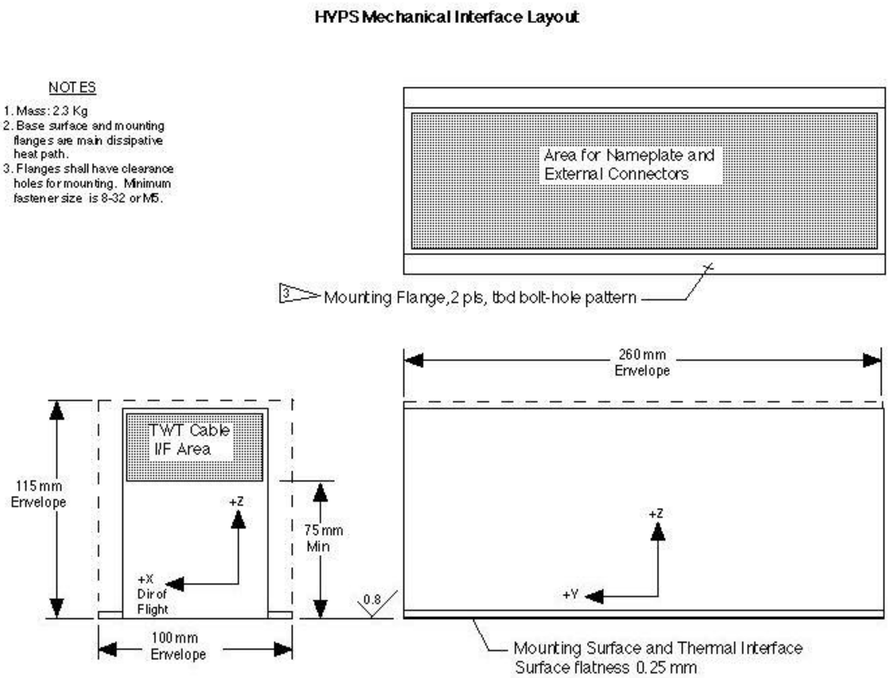


Figure 14 - HVPS Mechanical Interface Layout

7. VERIFICATION METHODS

The following methods shall be used to verify compliance with the requirements.

7.1. Similarity

Similarity may be used as evidence of conformance to a requirement, when the component is used in an existing or similar design, as it pertains to the requirement, that has been qualified to equal or more stringent requirements than that of the subject component.

7.2. Design

Design is used as evidence of conformance where the conformance is an inherent characteristic of the design.

7.3. Analyses

Analyses may be used as evidence of conformance, where verification by test is not feasible, to account for parameter variation effects and in support of other verification methods.

7.4. Inspection

Inspection shall be used as evidence of conformance where physical inspection or measurements will demonstrate conformance or non-conformance to the requirement.

7.5. Test

Test shall be used as the primary evidence of conformance. When conformance cannot be verified by a test in a cost effective, satisfactorily manner, one or more of the previously mentioned methods may be used.

8. QUALIFICATION AND PROTOFLIGHT TESTS

The TWTA shall exhibit no failure, malfunction, or out-of-tolerance performance as a result of the examinations and test specified herein. Any such failure, malfunction, or out-of-tolerance performance shall be subject to formal JPL review, prior to final acceptance or rejection.

8.1. Preparation for Test

Prior to TWTA acceptance and qualification testing, a conformance test of the Special Test Equipment (STE) shall be performed to verify that the STE provides the necessary functions and conditions for the TWTA testing.

8.2. Environmental Test Conditions

The test shall provide the different test conditions for the Engineering/Qualification Model (EQM) and the Protoflight models (PFM) as described herein.

8.3. Measurement Uncertainty

The measurement uncertainty of the tests shall not exceed the values indicated in Table VI. Verification of accuracy shall be by analysis, measurement, certification or a combination of the aforementioned methods. Summation of sources of error may be performed by the root-sum-square (RSS) method. Verification of measured specification values shall be based on measured data, excluding the measurement tolerances. The accuracy of the instruments and test equipment shall be verified periodically by calibration procedures as specified in MIL-STD-45662 or equivalent JPL-approved document.

Table VI - Measurement Uncertainty

Paramet	Uncertainty (RSS)
Frequency	1 part per million (ppm)
Gain	±0.25 dB
Output RF Power, Average	±0.3 dB
Harmonic Output Power	±2.5 dB
Spurious Signal	1.0 dB
VSWR	0.1
DC Power, Average	±0.7%
Temperature	±1°C

9. Quality Assurance Provisions

The Quality Assurance Program shall be in accordance with the requirements defined in D - 11141.

9.1. Materials and processes Control Requirements

Hardware shall be designed, manufactured, assembled and handled in the manner specified in D - 11151.

9.2. Part Requirements

9.2.1. Standard/Nonstandard Part

The minimum level of standard parts for the project shall be according to 311-INST-001. For all nonstandard parts, Nonstandard Part Approval Requests (NSPARS) are required to be approved by JPL. The purpose of the NSPAR is to document how the part is going to be used, and what inspection, analysis, and testing is required to qualify it for that application.

The operation of all flight parts shall be within manufacturer's specifications following exposure (2x) the expected total dose environment. Enhanced Low Dose Rate Susceptibility (ELDRS) and testing shall be evaluated for linear bipolar devices& Bi CMOS devices.

9.2.2. Semiconductor Devices

All semiconductor devices shall be evaluated for single event upset, latchup, burnout and gate rupture susceptibility. If previous data is not available characterization testing shall be performed.

- SEU - No upsets during SEU testing at an LET of 75 MeV/mg/cm^2 at a fluence of 10^7 ions/ cm^2.
- SEL - No latchup up to an effective LET = 75 MeV/mg/cm^2 and a fluence of 10^7 ions/ cm^2.
- SEGR- No single event gate rupture up to LET=37 MeV-cm^2 /mg and fluence of 10^6 ions/ cm^2.
- SEB- No single event burn out up to LET=37 MeV-cm^2 /mg and fluence of 10^6 ions/ cm^2.

All custom hybrid, Multi-Chip Module, MMICs, and High-Density Interconnect microcircuits shall meet MIL-PRF-38534, Class K requirements.

9.2.3. ASIC Process

All ASIC processes shall meet the reliability standards for design methodology, testability, fabrication, and assembly as specified in MIL-PRF-38535.

9.2.4. Precap Visual Inspection

Precap visual inspection required on all MMICs, hybrids. PIND, DPA, and RGA required per SSQA2001e of each manufacturer lot.

Part traceability from manufacturer to board installation is required (minimum lot date code).

9.2.5. Packaging/Process Validation

The TWTA packaging design approach and processes shall be validated by thermal cycling representative sample(s) of key design elements for 200 cycles from – 55 C to +100C. Cycling at ambient pressure is considered acceptable for this validation. An alternate validation approach may be used if equivalence is shown.

9.3. Verification

The following Table VII defines the verification methods.

Table VI - Verification Matrix

Req Nr.	Requirement	Similarity	Design	Analysis	Inspection	Test
2.1.	Functional Requirements					
2.1.1.	TRAVELING-WAVE-TUBE AMPLIFIER (TWTA)					
2.1.2.	TWT Functions					
2.1.3.	HVPS Functions					
2.1.3.1.	Self protection Trip Function					
2.1.3.2.	Telemetry and Direct Access Functions					
2.1.3.3.	Synchronization of Power Converter					
2.2.	General Requirements					
2.2.1.	Conformance to Interface Control Drawing				?	
2.2.2.	Mission Assurance			?	?	
2.2.3.	Interchangeability and replaceability		?			
2.2.4.	Useful life					
2.2.4.1.	Operating Hours			?		
2.2.4.2.	Filament on/off Cycles	?				
2.2.5	Performance Requirements					
2.3.	RF Performance Requirements					
2.3.1.	Operating Frequency Range					?
2.3.2.	RF Input Power (RF Drive)required for saturation					
2.3.2.1.	Saturation Drive					?
2.3.2.2.	Saturation Drive Variation					?

Req Nr.	**Requirement**	**Similarity**	**Design**	**Analysis**	**Inspection**	**Test**
2.3.3.	TWTA Input and Output VSWR					?
2.3.4.	Source and Load VSWR					?
2.3.5.	Pulsed RF Output Power					?
2.3.5.1.	Peak RF Output Power Level			?		?
2.3.5.2.	Output Power Control - "Grid Step"			?		?
2.3.6.	Output Power Variations					
2.3.6.1.	Short Term Variation (30 seconds)					?
2.3.6.2.	Maximum Variation over the Frequency Band					?
2.3.6.3.	Drive Dependent Variation					?
2.3.7.	Pulse Control Signal Characteristics					
2.3.7.1.	Pulse Control Signal Form		?			
2.3.7.2.	Pulse Width					?
2.3.7.3.	Pulse Repetition Interval					?
2.3.7.4.	Duty Cycle Limit					?
2.3.8.	RF Pulse Characteristics					
2.3.8.1.	RF Pulse Rise Time					?
2.3.8.2.	Pulse RF Fall Time					?
2.3.8.3.	Pulse Flatness					?
2.3.8.4.	Pulse Overshoot					?
2.3.9.	Control Signal – RF Output Timing Relations					
2.3.9.1.	Pulse Control Signal Waveform					?
2.3.9.2.	Turn On Delay Time					?
2.3.9.3.	Turn On Delay Time Variation					?
2.3.9.4.	Turn Off Delay Time					?

Req Nr.	**Requirement**	**Similarity**	**Design**	**Analysis**	**Inspection**	**Test**
2.3.9.5.	Turn Off Delay Time Variation					?
2.3.10.	Spurious and Harmonic Output					
2.3.10.1.	Spurious Signal					?
2.3.10.2.	Harmonic Content					?
2.3.11.	Output Noise Power Density					?
2.3.12.	Unconditional Stability					?
2.3.13.	Phase Shift – Group Delay					?
2.3.14	Voltage Breakdown					
2.3.14.1	Breakdown Under Normal Operation Condition (hard vacuum and atmospherics)					?
2.3.14.2	Breakdown Under Partial Vacuum					?
2.3.15.	RF Breakdown Margin			?		?
2.3.16.	No RF Drive					?
2.3.17.	RF Overdrive					?
2.3.18.	RF Drive Transition During Beam-on Pulse					?
2.4.	DC Power Consumption					?
2.4.1.	Variable Pulse Width Power Consumption					?
2.5.	HVPS Requirements					
2.5.1.	Gain and Phase Margin			?		
2.5.2.	Tolerance of arcs, stored energy			?		?
2.5.3.	Converter Synchronization					?
2.6.	28 V POWER BUS					
2.6.1.	Bus Source Characteristics					
2.6.1.1.	Bus Voltage					?
2.6.1.2.	Bus Source Impedance					

Req Nr.	Requirement	Similarity	Design	Analysis	Inspection	Test
2.6.1.3.	Bus Voltage Transients					?
2.6.1.4.	Anomalous Voltage					?
2.6.2.	Bus Return		?			
2.6.3.	Undervoltage protection					?
2.6.4.	DC Input Filter		?			
2.6.5.	Rate-of-Change of TWTA Input Current and Inrush Current Limit					?
2.6.6.	TWTA Induced Reverse Bus Current					?
2.6.7.	TWTA Induced Reverse Bus Voltage					?
2.6.8.	Input Filter Resonant Frequency			?		
2.6.9.	Over Voltage Protection			?		?
2.6.10.	Power Removal					?
2.7.	Grounding and Returns					
2.7.1.	28 V Bus Return		?			
2.7.2.	Temperature Telemetry Returns		?			
2.7.3.	Analog Telemetry Return		?			
2.7.4.	Digital Telemetry and Control Return		?			
2.7.5.	Power Converter Synchronizing Signal Return		?			
2.7.6.	Direct Access Returns		?			
2.7.7.	Chassis Ground		?			?
2.7.8.	Ground and Return Isolation					?
2.8.	Junction Temperature Limits			?		
2.9.	Protection (Trip) Circuits					?
2.9.1.	Helix Current Trip					?
2.9.2.	Bus Under Voltage Trip					?

Req Nr.	Requirement	Similarity	Design	Analysis	Inspection	Test
2.9.3.	Converter current Trip					?
2.10.	Telemetry					
2.10.1.	Redundant Telemetry Circuits		?			
2.10.2.	Output Voltage Limits			?		
2.10.3.	Telemetry channel failures			?		
2.10.4.	No damage from shorts to ground returns		?			
2.10.5.	Analog Telemetry Characteristics			?		?
2.10.5.1.	Channel Calibration					?
2.10.5.2.	Channel Accuracy			?		?
2.10.5.3.	Channel Source and Load Impedance			?		
2.10.5.4.	Channel Isolation					?
2.10.5.5.	Feedback current Immunity			?		
2.10.5.6.	TWT Helix Current					?
2.10.5.7.	TWT Beam Current Control Voltage					?
2.10.5.8	TWTA Bus Current					?
2.10.6.	Temperature Telemetry					?
2.10.7.	TWTA Digital Status Signals					
2.10.7.1.	Signal Level Definition					?
2.10.7.2.	Channel Source Impedance			?		
2.10.8.	Direct Access		?			
3.	Connectors			?		
3.1.	Power Connector				?	
3.2.	Command and Telemetry Connector				?	
3.3.	Direct Access Connector				?	

Req Nr.	Requirement	Similarity	Design	Analysis	Inspection	Test
3.4.	RF Connectors					
3.4.1.	RF Input				?	
3.4.2.	RF Output				?	
4.	TWT/HVPS Connections					
4.1.	Cable Length				?	
4.2.	Shielded harness				?	
5.	Burn-In					
5.1.	HVPS					?
5.2.	TWT					?
5.3.	TWTA					?
6.	Environmental Design Requirements					
6.1.	Ground Operations, Container and Handling Environment					
6.1.1.	Temperature and Pressure Environment.				?	
6.1.2.	Humidity Environment				?	
6.1.3.	Shipping and Transportation		?		?	
6.2.	Space Environmental Design Requirements					
6.2.1.	Temperature Limits					?
6.2.2	Temperature dwells					?
6.2.3	Temperature Transitions					?
6.2.4	Thermal Vacuum Profile					?
6.2.4.1.	Consistency of Thermal Vacuum Transitions					?
6.2.5.	Pressure Decay					?
6.2.6.	Vacuum					?
6.2.7.	Thermal Vacuum					?

Req Nr.	Requirement	Similarity	Design	Analysis	Inspection	Test
6.2.8.	Random Vibration, Traveling Wave Tube Amplifier (TWTA)					?
6.2.9.	Structural Resonance			?		?
6.2.10.	Pyrotechnic Shock					?
6.2.11.	Radiation Hardness			?		
6.2.12.	Internal Charging		?			
6.2.13.	Electromagnetic Compatibility Design Requirements					
6.2.13.1.	Power Line Conducted Emission Ripple					
6.2.13.1.1	CE01/03 Noise Current on Power Lines					?
6.2.13.1.2	Conducted Emissions (CE06)					?
6.2.13.1.3	Noise Voltage On Power Lines (CE11)					?
6.2.13.2.	Conducted Susceptibility Ripple (CS01, CS02)					?
6.2.13.3.	Conducted Susceptibility Transients (CS06)					?
6.2.13.4.	Radiated Emission Low Frequency Magnetic Field (RE01)					?
6.2.13.5.	Radiated Emission (RE02)					?
6.2.13.6.	Radiated Susceptibility, Electric Field (RS02)					?
6.2.13.7.	Radiated Susceptibility					?
6.2.14.	Magnetic Field, Design Requirements					
6.2.14.1.	Magnetic Field Susceptibility					?
6.2.14.2.	Magnetic Field Emissions					?
6.3.	STRUCTURAL DESIGN					
6.3.1.	Limit Loads			?		
6.3.2.	Strength					
6.3.2.1.	Materials			?		

Req Nr.	Requirement	Similarity	Design	Analysis	Inspection	Test
6.3.2.2.	Factor of Safety			?		
6.3.2.3.	Margins of Safety			?		
6.3.3.	Fatigue, Thermal, and Non-linearity					
6.3.3.1	Fatigue			?		
6.3.3.2	Thermal Effects			?		
6.3.3.3	Non-linearity			?		
6.4.	Mechanical Requirements		?			
6.4.1.	Dimensions				?	
6.4.2.	Mass				?	
6.4.3.	Identification and Marking				?	
6.4.4.	Connector Accessibility				?	
6.4.5.	Venting					?
6.4.6.	Cooling					?
6.4.7.	Finish				?	
9.2.	Part Requirements					
9.2.1.	Standard/Nonostandard Part					
9.2.2.	Semiconductor Devices		?			
9.2.3.	ASIC Process		?			
9.2.4.	Precap Visual Inspection				?	
9.2.5.	Packeging/Process Validation	?				

10. Test Matrix

The following Table VIII, describes the tests to be performed on the EQM and FM TWTA.

Q= Qualification (EQM)

P = Protoflight Model (PFM)

Table VIII -Test Matrix

Requirement		**Before Integration**		**After Integration into TWTA**					
Req Nr.	**Description**	**HVPS**	**TWT**	**Initial Functional**	**Burn In**	**Vibration**	**Thermal Vacuum**	**EMC**	**Final Functional**
2.3.1.	Operating Frequency Range			Q,P			Q,P	Q,P	Q,P
2.3.2.1.	Saturation Drive			Q,P			Q,P		Q,P
2.3.2.2.	Saturation Drive Variation						Q,P		
2.3.3.	TWTA Input and Output VSWR			Q,P					Q,P
2.3.4.	Source and Load VSWR			Q					
2.3.5.	Pulsed RF Output Power			Q,P	Q,P		Q,P	Q,P	Q,P
2.3.5.1.	Peak RF Output Power Level			Q,P	Q,P		Q,P	Q,P	Q,P
2.3.5.2.	Output Power Control - “Grid Step”	Q,P							
2.3.6.1.	Short Term Variation (30 seconds)			Q,P			Q,P		Q,P
2.3.6.2.	Maximum Variation over the Frequency Band			Q,P			Q,P		Q,P
2.3.6.3.	Drive Dependent Variation			Q,P			Q,P		Q,P
2.3.7.2.	Pulse Width			Q,P			Q,P		Q,P
2.3.7.3.	Pulse Repetition Interval			Q,P			Q,P		Q,P
2.3.7.4.	Duty Cycle Limit			Q,P			Q,P		Q,P
2.3.8.1.	RF Pulse Rise Time			Q,P			Q,P		Q,P
2.3.8.2.	Pulse RF Fall Time			Q,P			Q,P		Q,P
2.3.8.3.	Pulse Flatness			Q,P			Q,P		Q,P

Requirement		Before Integration		After Integration into TWTA					
Req Nr.	**Description**	**HVPS**	**TWT**	**Initial Functional**	**Burn In**	**Vibration**	**Thermal Vacuum**	**EMC**	**Final Functional**
2.3.8.4.	Pulse Overshoot			Q,P			Q,P		Q,P
2.3.9.1.	Pulse Control Signal Waveform			Q,P					
2.3.9.2.	Turn On Delay Time			Q,P			Q,P		Q,P
2.3.9.3.	Turn On Delay Time Variation			Q,P			Q,P		Q,P
2.3.9.4.	Turn Off Delay Time			Q,P			Q,P		Q,P
2.3.9.5.	Turn Off Delay Time Variation			Q,P			Q,P		Q,P
2.3.10.1.	Spurious Signal			Q,P			Q,P	Q,P	Q,P
2.3.10.2.	Harmonic Content			Q,P				Q,P	Q,P
2.3.11.	Output Noise Power Density			Q,P				Q,P	Q,P
2.3.12.	Unconditional Stability			Q,P			Q,P		
2.3.13.	Phase Shift – Group Delay			Q,P			Q,P		Q,P
2.3.14.1	Breakdown Under Normal Operation Condition (hard vacuum and atmospherics)			Q,P			Q,P		Q,P
2.3.14.2	Breakdown Under Partial Vacuum						Q,P		
2.3.15.	RF Breakdown Margin		Q						
2.3.16.	No RF Drive			Q,P					
2.3.17.	RF Overdrive			Q,P					
2.3.18.	RF Drive Transition During Beam-on Pulse			Q,P					Q,P
2.4.	DC Power Consumption			Q,P			Q,P		Q,P

Requirement		**Before Integration**		**After Integration into TWTA**					
Req Nr.	**Description**	**HVPS**	**TWT**	**Initial Functional**	**Burn In**	**Vibration**	**Thermal Vacuum**	**EMC**	**Final Functional**
2.4.1.	Variable Pulse Width Power Consumption			Q,P			Q,P		Q,P
2.5.2.	Tolerance of arcs, stored energy	Q,P							
2.5.3.	Converter Synchronization	Q,P							
2.6.1.1.	Bus Voltage			Q,P			Q,P		Q,P
2.6.1.3.	Bus Voltage Transients			Q,P					Q,P
2.6.1.4.	Anomalous Voltage			Q					Q
2.6.3.	Undervoltage protection	Q,P		Q,P			Q,P		Q,P
2.6.5.	Rate-of-Change of TWTA Input Current and Inrush Current Limit			Q,P			Q,P		Q,P
2.6.6.	TWTA Induced Reverse Bus Current			Q			Q		Q
2.6.7.	TWTA Induced Reverse Bus Voltage			Q			Q		Q
2.6.9.	Over Voltage Protection			Q					Q
2.6.10.	Power Removal			Q					
2.7.7.	Chassis Ground			Q,P					Q,P
2.7.8.	Ground and Return Isolation			Q,P					Q,P
2.9.	Protection (Trip) Circuits	Q,P							
2.9.1.	Helix Current Trip	Q,P							
2.9.2.	Bus Under Voltage Trip	Q,P		Q,P			Q,P		Q,P
2.9.3.	Converter current Trip	Q,P							
2.10.5.	Analog Telemetry Characteristics	Q,P		Q,P					Q,P

Requirement		**Before Integration**		**After Integration into TWTA**					
Req Nr.	**Description**	**HVPS**	**TWT**	**Initial Functional**	**Burn In**	**Vibration**	**Thermal Vacuum**	**EMC**	**Final Functional**
2.10.5.1.	Channel Calibration	Q,P							
2.10.5.2	Channel Accuracy	Q,P							
2.10.5.4.	Channel Isolation	Q,P		Q,P					Q,P
2.10.5.6.	TWT Helix Current	Q,P							Q
2.10.5.7.	TWT Beam Current Control Voltage	Q.F							
2.10.5.8	TWTA Bus Current	Q,P		Q,P			Q,P		Q,P
2.10.6.	Temperature Telemetry	Q,P					Q,P		
2.10.7.1.	Signal Level Definition	Q,P							
5.1.	HVPS Burn-in	Q,P							
5.2.	TWT Burn-in		Q,P						
5.3.	TWTA Burn-in				Q,P				
6.2.1.	Temperature Limits						Q,P		
6.2.2	Temperature Dwells						Q,P		
6.2.3.	Temperature Transitions						Q,P		
6.2.4.	Thermal Vacuum Profile						Q,P		
6.2.4.1.	Consistency of Thermal Vacuum Transitions						Q,P		
6.2.5.	Pressure Decay						Q,P		
6.2.6.	Vacuum						Q,P		
6.2.7.	Thermal Vacuum						Q,P		

Requirement		**Before Integration**		**After Integration into TWTA**					
Req Nr.	**Description**	**HVPS**	**TWT**	**Initial Functional**	**Burn In**	**Vibration**	**Thermal Vacuum**	**EMC**	**Final Functional**
6.2.8.	Random Vibration, Traveling Wave Tube Amplifier (TWTA)					Q,P			
6.2.9.	Structural Resonance					Q,P			
6.2.10.	Pyrotechnic Shock					Q			
6.2.13.1.1	CE01/03 Noise Current on Power Lines							Q,P	
6.2.13.1.2	Conducted Emissions (CE06)							Q,P	
6.2.13.1.3	Noise Voltage on Power Lines (CE11)							Q,P	
6.2.13.2.	Conducted Susceptibility Ripple (CS01, CS02)							Q,P	
6.2.13.3.	Conducted Susceptibility Transients (CS06)							Q,P	
6.2.13.4.	Radiated Emission Low Frequency Magnetic Field (RE01)							Q,P	
6.2.13.5.	Radiated Emission (RE02)							Q,P	
6.2.13.6.	Radiated Susceptibility, Electric Field (RS02)							Q,P	
6.2.13.7.	Radiated Susceptibility							Q,P	
6.2.14.1.	Magnetic Field Susceptibility							Q,P	
6.2.14.2.	Magnetic Field Emissions							Q,P	
6.4.5.	Venting						Q,P		
6.4.6.	Cooling						Q,P		